ISSN: 1119-1449
Nigerian-German Kainji Lake Fisheries Promotion Project
Technical Report Series 11.

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by M.D.B. Seisay and T.A. du Feu

Nigerian-German (GTZ)
Kainji Lake Fisheries
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November, 1997

ISBN 978-037-010-2
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New Bussa
Niger State
Nigeria

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Acknowledgement

We would like to express our gratitude to the project's counterpart organisation "The National Institute for Freshwater Fisheries Research" (NIFFR) in New Bussa for allowing the project to utilise their old gill net trial data.

Our sincere thanks go to Mrs. Marina Mdaihli, the Project Adviser for her advice and support and, in particular, her editing of the final text.

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Executive Summary

This report is an assessment of the gillnet fishery in Kainji Lake from 1969 to present on the basis of data sets from commercial and experimental gillnet fishing with the purpose to detect trends in some key fishery monitoring indicators.

There has been an increase in the number of small meshed nets in the fishery resulting in a shift in the mode to lower mesh sizes between 1969 and 1997. Consequently, the average mesh size declined gradually in the fishery. The trend is found to be directly correlated with the decline in the Cpue and mean weight of the fish species. For example the cpue of *Citharinus spp* declined from 6.0kg/gillnet bundle to 0.53kg/gillnet bundle and the mean weight reduced from 1.46kg to 0.07kg.

It is argued that the observed trend in Cpue and mean weight is forcing the fishermen to switch effort to gears like traps which have very small meshes and can indiscriminately take all sizes of fish.

A review of species abundance by mesh size showed that Cpue and mean weight increase with increasing mesh sizes for *Citharinus spp*, *Lates niloticus*, *Labeo spp* etc. but with a decreasing trend, especially after 3.0 to 3.5 inches, for most of the small to medium sized species like *Alestes spp* and *Chysichthys spp*. This justifies the 3.0" minimum mesh size regulation in the Lake since the loss in yield after implementation of the regulation will not be too spectacular whilst awaiting the time that the bigger fish becomes accessible to this mesh size.

In experimental gill netting in 1996 the Cpue was much lower than in the commercial fishery the reason possibly being irresponsible fishing practices by the gillnet fishermen. If exclusively the commercial data would be relied on for fisheries management it could cause a falsely optimistic forecast.

It is shown that the catch composition by weight of *Citharinus citharus*, *Lates niloticus* and Tilapia declined in the gillnet fishery in the late 1970's and early 1980's. Recent data, from 1994 to 1996, however indicates that *Citharinus citharus* is recovering but with declining mean weight. This goes to say the exploitation pattern is shifting to the smaller fish through the use of small meshed nets.

In general however, there has not been drastic changes in species bio-diversity in the Lake as a result of predatory effect and ecosystem overfishing as it has happened in other great African Lakes like Victoria in Kenya and Lake Malombe in Malawi. The species composition since lake formation continued to be dominated by fewer than 20 species.

The potential yield for the lake has been estimated to be 32,166 tonnes (excluding Clupeids) and the required optimum fishing effort to be 1,814 fishing canoes.

In view of the relative stability of the species diversity in the Lake and the current fish production level it is proposed here that this MSY be adopted for all species.

This would be achieved with the current effort level in the lake assuming the efficiency of the fishermen and their gears do not improve. It should be reviewed after 10 or more years of catch and effort data collection.

Growth (K and L_{inf} and t_o) and mortality parameters were estimated for selected species. The results indicated that for most species belonging to the same family separate stock assessments must be undertaken, e.g. for the *Synodontis spp* and the Tilapias. For the two Bagrus species (*Bagrus docmac* and *Bagrus bayad*) combined stock assessment studies can be carried out since their growth parameters are comparable.

Length based cohort analysis was carried out for *Synodontis membranaceous*, *Citharinus Citharus* and *Lates niloticus*. The analysis produced, for each species, the estimated fish population number per size group and the number of fish that recruited into the fishable part of stock.

More importantly, the distribution of fishing mortality (fishing effort) per size groups was estimated. In *Synodontis membranaceous,* inspite of the increasing number of small meshed gillnets it is revealed that fishing mortality is highest on the matured stages of the population and relatively stable at low levels on the juvenile/immature stages probably as a result of it's high fecundity. This is considered as an ideal fishing pattern for this species especially if it can spawn at least once before being cropped.

The situation is critical for *Citharinus citharus*, which have been exploited by gillnets for decades. The exploitation rate rises gradually and becomes constant ($E \geq 0.5$) on the maturing and matured adults. This pattern of fishing mortality is attributed to small meshed nets like drift nets, cast nets and beach seines (and small meshed gillnets). It is recommended that those fisheries be evaluated to establish their impact on the stocks.

In *Lates niloticus*, fishing effort is exerted throughout on the immature stages. This presupposes that large population of mature and spent stages of *Lates niloticus* may be present in the Lake.

The biomass of *Synodontis membranaceous* and *Citharinus citharus* were estimated as 8,058mt and 5,600mt respectively. This indicates that 26% and 52% respectively of the standing stock biomass are currently taken by all gears annually. Normally, half of the estimated biomass for each species could be postulated as the MSY.

Prediction of yield and biomass at different levels of effort, by adjusting upwards and downwards the current (1996) fishing effort, showed a rapid decline in biomass of each of these species whilst the increase in yield with increasing effort is marginal.

It is recommended that at best the current effort be maintained. It is believed that with the current mesh size regulation and the high fecundity of some species, the continuity of the stocks will be assured.

1. Introduction

Lake Kainji was created in 1968 primarily to cater for the electric power needs of Nigeria. It has a maximum surface area of 1,270 km^2 and supports a large variety of fish species. At least over 100 species have been identified and described in the lake (Ita, 1982). The lake is the second largest fresh water body in Nigeria and was very extensively studied until 1981.

There was a lull in fisheries assessment activities after this period. Most of the fisheries bio-statistical data available after 1981 has been based on some form of approximation.

By all indicators the lake could contribute, in no small measure, to alleviating the nutritional problems and poverty level in the Kainji area on a sustainable basis if proper and rational fisheries management practices are instituted. The Government of Nigeria recognized this and thus requested assistance from the German Government in this direction.

The Nigerian-German (GTZ) Kainji Lake Fisheries Promotion Project (KLFPP) commenced it's activities in 1993 with the purpose to prepare and implement a fisheries management plan for the sustainable exploitation of the fisheries resources of Kainji Lake.

In order to assess the development in the Lake fishery in past and present, data previously collected, but not analysed had to be reviewed as well as new data collection systems had to be introduced. For example, there were some 4,100 records available obtained by the KLRI during previous gillnet experimental fishing trials (1969-1978) that had to be computerised, containing information on Catch-per-unit-of-effort (Cpue) and species abundance. The project replicated the fishing trials, further recording 2,000 separate net records.

Data from 1970 to 1980 collected by the then Kainji Lake Research Institute (KLRI) in a boat-based Catch Assessment Survey (CAS) were computerized, adding to the 22,000 records available now from the gear based Catch Assessment Survey introduced by the project.

To discover changes in the Cpue and fish abundance to determine the factors responsible for fishermen's adoption of certain gears and mesh sizes the relationship within the data sets as well as between the data sets of the past and the recently collected data had to be established.

2. Terms of Reference

a. Familiarise with literature, gillnet trial and catch assessment databases for the Kainji Lake Fishery.
b. Determine relationships between the catch assessment surveys data and gillnet trial data, particularly for mesh size distributions, Cpue levels and species abundance from 1969-1997.
d. Describe the above relationships and relate them to changing fishing patterns within the fishery.
c. Report on findings.

3. Types of Data Analysed

The present analysis has been based on four data sets all of which are stored in separate project databases developed by du Feu (1997).
1. Experimental gillnet data: 1969 - 1978
   (Shagunu, 1970-1972, NIFFR data, 1969-1978))
2. Experimental gillnet data: 1996
3. Boat based catch assessment data (1969 - 1981)
4. Gear based catch assessment data (1994 - 1997)

Earlier analyses of some of the data has been undertaken by Bazigos (1974), Ekwemalor (1977), Ita (1984) and several others.

Data were extracted from some of these works and have been analyzed mainly for estimation of fish population parameters of selected commercially exploited fish stocks in the Lake area as recommended by Turner (1994).

The present study has endeavoured to avoid replication of what has already been done and this necessitated extensive literature review of available reports and consultation both with project staff and NIFFR scientists.

The following data were established:
a) mesh size distribution in the gillnet fishery from 1969 to date;
b) catch per unit of effort (Cpue), as an index of abundance of the various fish taxonomic groups in all mesh sizes and across the years, 1969 to date;
c) comparison of mean weight of selected fish species between various mesh sizes and across the years;
d) long-term changes in species composition, if any, between 1969 to date;

e) maximum sustainable yield (MSY) from catch and effort data estimated from boat-based catch assessment data 1970-1978 using Surplus Production Models;

f) age-at-length data of selected species for estimation of growth and mortality parameters;

g) combination of (f) with length frequency and catch statistics of major commercial species for Cohort analysis and prediction of yield and biomass

It should be noted that the analysis was hampered by the fact that the data from early fishery surveys were not complete.

4. Methods of Analysis

The dimensions of the nets in the old gillnet trials were 30 meters long and 3 meters wide whilst the new gillnet trial used nets of 50 meters length and 3 meters width. To make the results comparable the catch estimates, both in weight and number, for the old gillnet trial were multiplied by the factor 1.67.

4.1. Key Monitoring Indicators

<u>Mesh size distribution</u>
The frequency distribution of the mesh sizes in use for the period the between 1960 to 1997 was determined and the mean mesh size and standard deviation was calculated.

<u>Variation in Cpue</u>
The variation in Cpue (species abundance) between the years and in different mesh sizes was calculated for all the major species. Statistical comparison, using paired t-test, of Cpue between
(a) old CAS and new CAS data;
(b) old CAS data and old gillnet trial data;
(c) new CAS and new gillnet trial data; and
(d) old gillnet trial and new gillnet trial data
was also performed.

<u>Variation in mean weight</u>
Variation in mean weight of commercially exploited fish species from catch assessment and gillnet survey data were investigated and the mean values in different mesh sizes were compared statistically.

<u>Changes in species composition</u>
The percentage contribution of various species to the total landings, from 1969 to 1996, were determined and comparison made in order to establish any major change in the average catch composition of each species.

4.2. Estimation of Potential Yield and Optimum Effort

Long-term time series of total fish catch and corresponding fishing effort between 1969 and 1978 were retrieved from Ita (1984) and subjected to further in-depth analysis for estimation of Maximum Sustainable Yield (MSY) and the optimum fishing effort (F_{opt}) required to achieve this MSY. Global Surplus Yield Production models of Schaefer (1954) and Fox (1970) were fitted to the data and the corresponding statistics evaluated for goodness-of-fit. To assess the effect of last year fishing effort on the current year, the original effort figures were transformed into a two-moving-average value.

Both models assume that the catch and effort data are coming from a fishery where recruitment and growth into the fish stocks are balanced out by mortality (equilibrium). The models are based on the reasoning that at the beginning of the fishery, fish catches increase with increasing fishing effort until a maximum (MSY) is attained when further increase in effort produces only reduced catches (over fishing). Schaefer model predicts complete extinction of fish species at exceedingly high levels of fishing efforts beyond F_{opt} whilst Fox model predicts diminished catches in heavily fished stocks when the optimum fishing level is overshot.

4.3. Estimation of Fish Population Parameters

Growth and mortality parameters are very central in the studies of the dynamics of fish populations since they can provide information on the long-term exploitation pattern and also serve as input parameters'in cohort (virtual population) analysis and predictive modelling. Literature review revealed bibliography of various scientists who have carried out aging of different fish species using hard parts (vertebrae, opercular bones, dorsal spines, otoliths, back calculation techniques etc.) and estimated mean length-at-age data (Appendix 1).

These data were never subjected to further analysis for fish stock assessment purposes except Balogun (1988) who estimated growth parameters of *Lates niloticus*. Four different graphical methods of growth parameter estimation were applied here. Growth parameters are obtained from such data by graphical methods or plots, which are always based on a conversion to a linear equation.

These are:

a) Gulland and Holt Plot (1959)
which plots growth increments against change in mean length over time. The growth parameters L_{inf} and K are derived from the slope and intercept of the regression line.

b) Ford-Walford Plot (1933, 1946) which plots mean length against the length one year after. The growth parameter L_{inf} can be obtained from the intersection point of the 45° diagonal line with the regression line. K is estimated from the intercept and slope.

c) Chapman Plot (1961)
which is a variant of the Ford-Walford plot and is based on constant time interval. The derivations of growth parameters are obtained from the slope and intercept of the regression line.

(d) von Bertalanffy (1934)
which only estimates K and t_o (hypothetical age at zero length) from the slope and the intercepts of the regression line and requires an input of L_{inf}.

The reliability of the different growth parameter estimates were statistically evaluated by comparison of the resultant growth curves, that is L_{inf} and K together, using the growth performance indices, phi prime, (ϕ) with the formula:

$$\text{Phi prime } (\phi) = \text{Ln } K + 2 * \text{Ln } L_{inf}$$

The factor is also used to compare growth estimates between species of the same family living in different environments.

The Fishing Mortality Rate (F) was estimated from the relationship:

$$Z = F + M$$

and the Exploitation Rate (E) from E= F/Z (proportion of death caused by fishing).

The total mortality rate (Z) was estimated from Jones (1974) length converted linearised catch curve analysis. The catch curve is a graphical representation of the logarithms of numbers caught plotted against age. In this analysis, however, the method is modified to accept length composition data as input data. This was possible since growth parameters K, L_{inf} and t_o have been estimated above and were used in the inverted von Bertalanffy formula below to convert length into age:

$$t(L) = t_o - 1/K^* \; Ln \; (1 - L/L_{inf})$$

t(L)=age at length L, L_{inf}=Length at infinity, t_o=hypothetical age at zero length.

The Z is estimated from the slope of the length converted catch curve with the sign reversed. The length composition data from the gillnet trial data of 1969-1978 was used. The age-based method was not used here since there was no data on number of fish at age.

The natural mortality rate (M) was estimated from Pauly's (1983) empirical formula describing M as a function of growth (L_{inf} , K) and the ambient temperature T °C. The value of 27.85 °C was chosen as the mean environmental water temperature of the Lake (Mbagwu and Adeniji, 1994). Since M is usually a difficult but important parameter to partly determine the yield and biomass curves, an alternative method of M estimation was considered using Rikhter and Efanov's (1959) method, which identifies a relationship between M and the age of massive maturation (t_{mass}) by fish species.

Detailed description of these methods can be found in stock assessment texts such as Sparre and Venema (1992) and reports like Seisay et al, 1992. Most of the analysis was done using FAO/ICLARM Fish Stock Assessment Tools (FiSAT) and Excel Spreadsheet for validation of results.

4.4. Cohort Analysis and Thompson and Bell Predictive Model

The sample length frequency data for selected species (*Citharinus citharus, Synodontis membranaceous and Lates niloticus*) in the gill net trial data were averaged across all the years for each of these species.

The data were then raised to total length composition of the catch by multiplying the numbers at each length group in the sample length frequency data by a constant.

The constant is derived from a ratio between sample weight and the estimated total catch of each species from catch assessment data (use of boat based catch assessment data was not possible since it did not provide breakdown of total estimated catch by species and gear type). The sample weight of each species was estimated by converting the number at length to weight at length using the length/weight relationship:

$$W = a*L^b$$

W=weight in gm, L=Length in cm, a and b are parameters of length/weight relationships, which have been estimated from gillnet experimental trial.

The raised total length composition data was then subjected to cohort analysis using input parameters as growth (L_{inf} and K) and mortality parameters (F_t (fishing mortality on the oldest length group) or E_t (exploitation rate of the oldest length group)). The analysis was possible for only these three species because of the limited data available.

The estimated fish population number per length group, from cohort analysis, is utilized in the Thompson and Bell analysis using the estimated number in the first length group as recruitment input for prediction of yield and biomass for each of the species. The estimated array of fishing mortality per length, from cohort analysis is also utilized in the predictive model. The output is yield and biomass estimate per length. The actual effort (standardized gillnet effort) that produces the current catch for each of the species was allowed to vary for long-term prediction of yield and stock biomass for various levels of fishing effort. Since cohort analysis requires total catch of each species from all gears all efforts of cast nets, traps, long lines, drift nets and beach seines that contributed to the total annual catches for each of the three species were converted into standard gillnet by the following standardization formula:

Standardized Gillnet Effort = catches of all gears/Cpue of Gillnet

5. Results and Discussion

5.1. Mesh Size and Species Abundance

It is revealed in this study that in the early years of the fishery, 1970 and 1971, the frequency distribution of mesh sizes was evenly spread across all sizes with mesh sizes of 3.0" (84 %) dominating the commercial fishery (Figure 1). Smaller mesh sizes actually started gaining prominence in the fishery after 1973 but, in spite of this, the mode of the distribution was maintained at 3.0" (607 nets). The situation dramatically changed for the worst from 1994-1997 with the number of gillnets of mesh sizes of 2.5" increasing in proportion to 46% (contrary to only 16% in the years between 1970-81). The modal frequency of the number of nets in use has shifted down by 0.5", that is to lower mesh size of 2.5", in these later years.

This was followed by a systematic decline in average mesh size from about 7.0" in 1970 to about 3.0" in 1996. The overall Cpue of fish species caught in the gillnet fishery also dropped from 9.08kg/gillnet bundle in 1970 to 3.67 kg/gillnet bundle in 1996 (Table 1). Progressive reductions in mesh sizes are normally an indication of a declining fishery as a result of reduction in mean sizes (i.e. mean length and weight) in fish species and changes in species composition due to both recruitment and ecosystem overfishing. In the case of the decline in Cpue and the mean weight, this claim appears to be corroborated here by the significant direct correlation between mean mesh sizes and Cpue ($r = 0.668$, $P=0.05$) and also mean weight ($r = 0.649$, $P=0.05$), of the combined commercial fish species in the gillnet fishery.

Figure 1. Mesh size distribution in the gillnet fishery

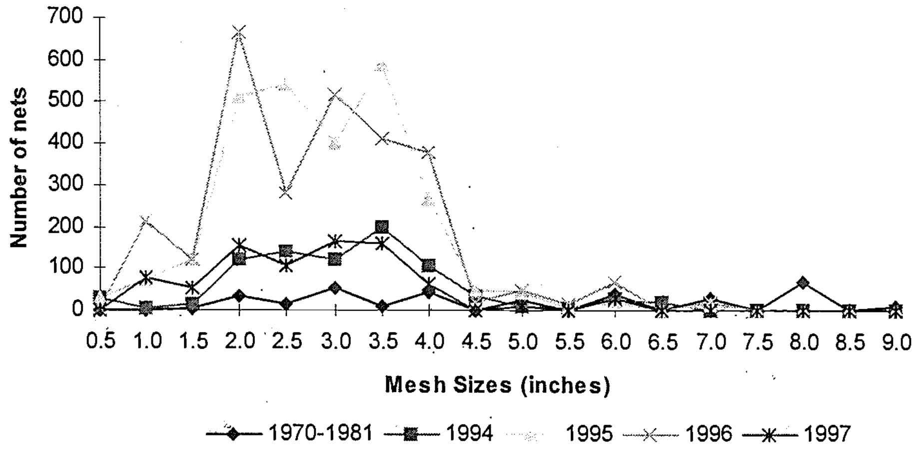
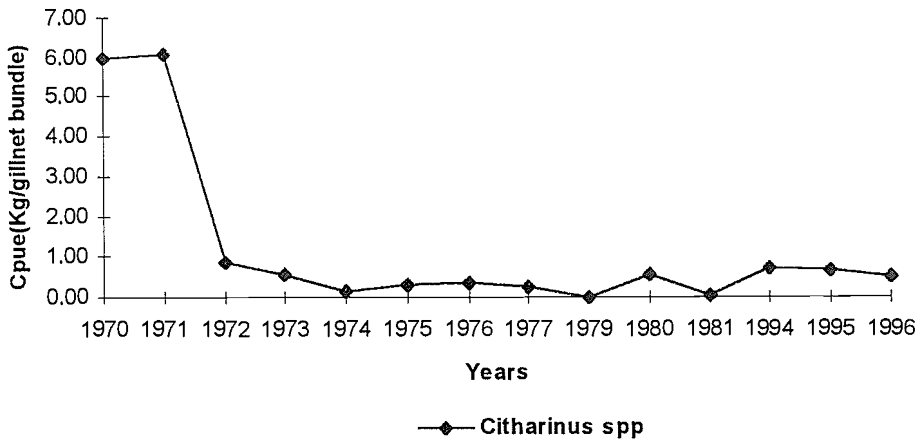


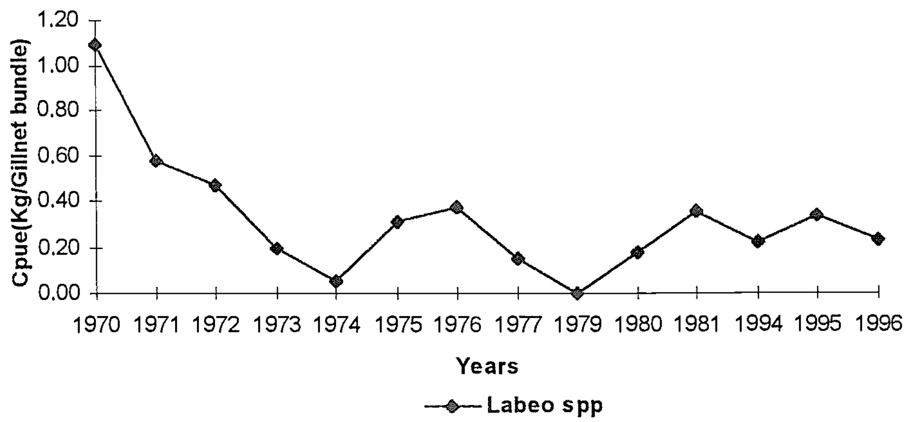
Table 1. Annual variation in mean mesh size in the commercial gillnet fishery

Year	Mean mesh (inches)	Range (inches)	Cpue (Kg/gillnet bundle)	Mean weight (Kg)
1970	6.80	2.9-9.0	9.08	8.95
1971	6.91	1.0-9.0	7.74	71.49
1972	4.07	1.0-8.0	8.15	11.61
1973	3.84	1.0-9.0	4.55	12.20
1974	3.30	1.0-7.0	2.35	12.75
1975	4.34	1.0-8.0	1.88	6.15
1976	4.20	2.0-9.0	3.52	8.54
1977	2.96	1.5-5.0	1.44	2.09
1979	3.25	3.0-3.5	0.72	0.00
1980	3.33	2.0-5.0	6.21	15.3
1981	3.14	2.0-4.0	4.26	0.79
1994	3.20	0.5-9.0	4.23	0.25
1995	2.57	0.5-9.0	3.76	0.15
1996	2.86	0.5-9.0	3.67	0.11
1997	2.78	2.6-6.5	3.68	0.14

The Cpue decline is illustrated in Figure 2 where species like *Citharinus spp*, and *Labeo spp* exhibited a progressive decline in both Cpue in weight and number between 1970 to 1996 whilst *Chysichthys* tend to exhibit an increasing trend in Cpue with time. Species like *Bagrus* and *Synodontis* also show a declining Cpue over the years in the gillnet fishery. For *Citharinus spp* the catch rate in the commercial fishery data declined considerably from about 6.0 kg/gillnet bundle/24 hours in 1970 to a mere 0.53 kg/gillnet bundle/24 hours in 1996, and similarly for *Labeo spp* from 1.09 to 0.23. The picture is far from clear for species like *Hydrocynus* and *Tilapia* due to the large noise in Cpue variation with time.

Figure 2. Annual variation in Cpue of selected species in the gillnet fishery





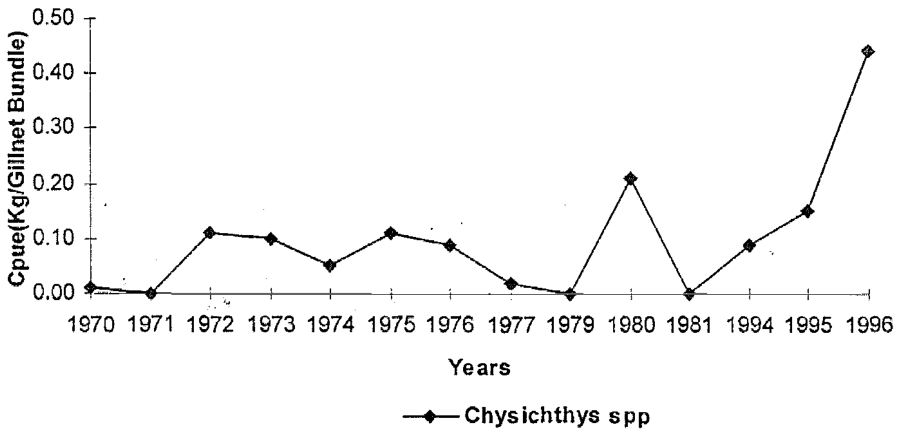
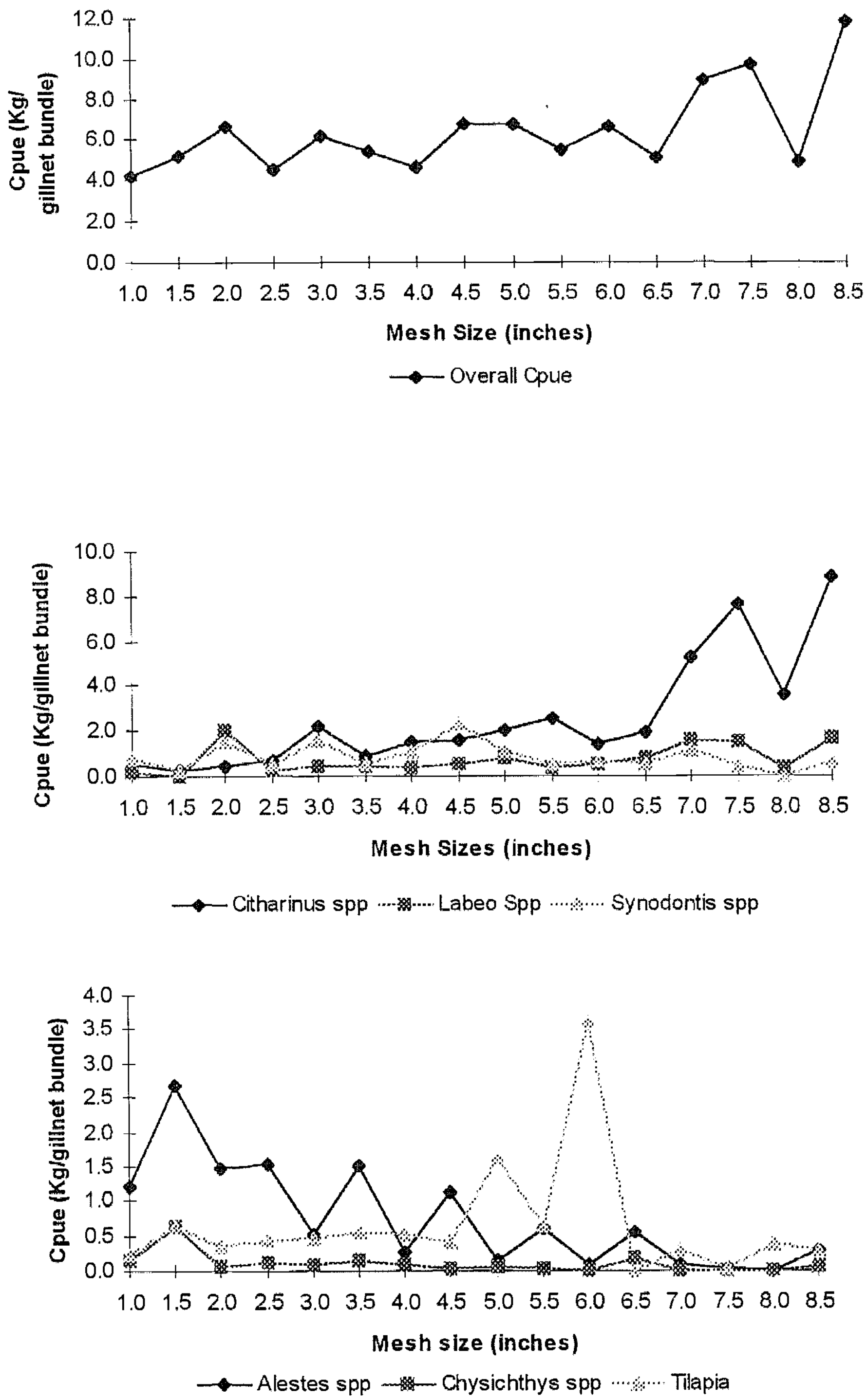


Figure 3 shows variation of Cpue with mesh sizes. In general the overall Cpue increases with increasing mesh size. This situation is very much clear for *Citharinus spp* (from 0.5 kg/bundle in 1.0" mesh to 8.9 kg/bundle in 8.5" mesh), suggesting that in the early years after impoundment the large meshed gillnet fishery was mainly sustained by this species and that the successive decline in catch rate over the year, both in number and weight, of this species is more or less dictating the mesh size distribution of the gillnet fishery. Species like *Labeo* also exhibit an increasing catch rate with increasing mesh size but in a less dramatic fashion. For the *Alestes spp* and *Chysichthys spp,* (from 0.64kg/bundle in 1.5" mesh to 0.0kg/bundle in 8.5" mesh), catch rates declined rapidly in mesh sizes of 1.5".

Figure 3. Variation in Cpue with mesh size in the gillnet fishery, 1970-96



There was sequential exploitation of fish stocks in Kainji Lake with the large meshed nets targeting at large species like *Citharinus*, *Labeo* etc. and the small meshed nets targeting at *Alestes spp* and *Chysichthys* spp. The effort of the small meshed gillnets is complimented by small meshed gears like cast nets, fish traps, drift nets and beach seines and these could pose a big threat to the current minimum 3.0" mesh size regulation, if the effect of these gears on the fish stocks are not immediately assessed. In any case the 3" minimum mesh size regulation would allow high valued species like *Citharinus*, *Labeo*, *Tilapia* etc. to grow to maturity, and at least spawn once before capture. This will ensure the continuity of the fishery for these species in view of their high fecundity. In addition the regulation would protect the juvenile/immature stages of species like *Chysichthys*, *Alestes*, *Bagrus*, *Hydrocynus* etc. which are mainly caught in these small meshed nets though they would still be exploited in the trap and beach seine fisheries. The exploitation of juvenile stages is evident by the increase in number of fish/kg for *Tilapia spp* and *Synodontis spp*.

Unfortunately, there was no catch record for *Lates niloticus* in the old catch assessment data. Recent trends in the new CAS data however suggest that the catch rates for this species in weight is low since the bulk of the catch consists of under sized juvenile and immature stages as will be revealed later in the text through cohort analysis. Analysis of both sets of experimental gillnet data revealed that the catch rate of this predatory carnivore has declined. This species can grow up to 70 kg and achieve a maximum length of 1,500 mm. The majority of the gillnets in use have mesh sizes which could not target this species. The main fishing gear exploiting the large sizes is the long line, which is not present in high numbers. A huge quantity of largely unexploited post mature stages of this species could thus be available in the Lake, as earlier assumed.

It should be noted that the overall increase in catch per day per fisherman in large mesh sizes tend to be uncertain and as such most fishers would not want to take the risk of buying a large meshed net. As a matter of fact the relationship between catch rate of all species and mesh sizes becomes very noisy at higher mesh sizes. This observation is important in a multispecies fishery like that of Lake Kainji since the fishers are interested in the overall catch at the end of the day and not only in one or two species.

Comparison of overall catch rates revealed that they are significantly much higher (P=0.05) in both the commercial catch and the old gillnet trial data than the new gillnet trial data. The catch rates in the old CAS data are significantly (P=0.05) higher than the current CAS gillnet fishery catch rates.

This could partly be explained by the domineering presence of large specimens of *Citharinus spp*, *Labeo spp* and perhaps *Lates niloticus* in the commercial gillnet fishery especially in the early post impoundment years.

The average catch rate of *Citharinus spp.* was 7.40 and 8.90 kg/gillnet bundle in the 7.0" meshed nets in the old gillnet trial and the old commercial data respectively whilst this rate has currently dropped to a mere 0.76 kg/gillnet bundle.

Table 2. Variation in Cpue per mesh size in commercial and experimental gill net data

Mesh size inch	Old CAS	New CAS	Exp. 1969/81	Exp. 1996
1.0	4.21	4.05		1.40
1.5	5.17	3.96	2.58	1.12
2.0	6.64	3.91	4.05	1.12
2.5	4.48	4.16	4.05	1.04
3.0	6.17	3.45	4.30	1.18
3.5	5.36	3.56		
4.0	4.61	4.05	5.00	1.72
4.5	6.68	3.77		
5.0	6.76	4.66	5.66	2.86
5.5	5.48	4.15		
6.0	6.58	3.96		
6.5	5.12	5.14		
7.0	8.90	4.41	9.99	5.28
7.5	9.69	4.16		
8.0	4.85	9.52		
Average	6.05	4.46	4.45	1.96
Std	1.57	1.50	2.83	0.73

The observed catch rates in the current commercial catch data could have been enhanced by the gillnet fishermen driving the fish into their fishing gears by beating the water in desperate attempt to increase their day's catch and hence their income. This practice became very common among gillnet fishermen in Lake Malombe in Malawi, immediately prior to the collapse of the Chambo (Tilapia) stocks.

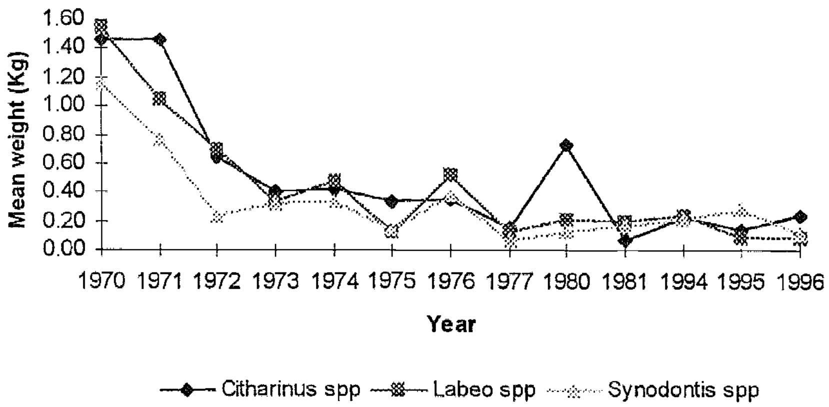
This enhanced effort for artificially increased catch rates can be misleading to give false optimistic forecast of the fishery when used as an index of abundance for planning purposes.

Another possibility is that the low catch rate in the new gill net trial data could be due to the non recording of large fish in the catch by the enumerators during the course of the experiment although the fishers were given the right to keep all fish caught in the experimental nets.

5.2. Changes in Mean Weight

As stated earlier, one of the indicators of overfishing in any fishery is the reduction in mean size of the fish caught. This situation arises as a result of recruitment and/or growth overfishing. Analysis of the commercial gillnet data clearly indicates that, as a whole, the overall mean weight have declined over the years (Figure 4). This decline is clearly noticeable in species like *Citharinus* (from 1.46kg to 0.07kg), *Labeo* (from 1.54 kg to 0.19kg), *Tilapia* (from 0.75kg to 0.09kg), *Alestes* (from 1.34kg to 0.17kg) and *Synodontis spp* (from 1.15kg to 0.17kg). This is attributed to increasing preponderance of small meshed gillnets over the years which crop these species before they grow to larger size. This trend is sure to continue if the present minimum mesh size regulation and the ban on the beach seine is not adhered to by the fishermen.

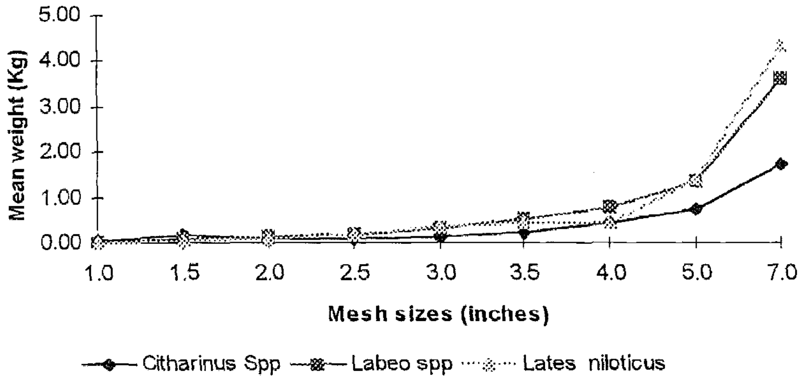
Figure 4. Variation in mean weight of selected species in the gillnet fishery



At mesh size level (Figure 5), there is an increase in mean weight with increasing mesh sizes for large species like *Citharinus citharus* (from 0.02kg in 1.0" to 1.69kg in 7.0" mesh), *Lates niloticus* (from 0.02kg in 1.0" to 4.33kg in 7.0" mesh) and *Labeo senegalensis* (from 0.02kg in 1.0" to 3.60kg in 7.0" mesh).

Species like *Bagrus bayad, Synodontis membranaceous* also exhibited the same pattern. With larger mesh sizes in excesses of 3.5" *Alestes baremose, Sarotherodon galilaeus, Synodontis ocellifer, Tilapia zillii, Schilbe mystus, Chysichthys nigrogiditatus* etc. become less abundant. On the overall, the mean weight increases from 0.48kg in 1.0" mesh to 10.61kg in 7.0" mesh.

Figure 5. Variation in mean weight with mesh size of selected species, 1970-96



The adoption of the current regulation will allow the juvenile/immature stages of species like *Citharinus citharus*, *Labeo Senegalensis*, *Tilapia spp.*, *Synodontis membranaceous*, *Bagrus spp*, *Lates niloticus* etc. to grow to maturity before harvesting them. This observation is further supportive of an earlier discussion that the time lag for the recovery of the Cpue and mean weight of the fish stocks in the fishery, after lakewide adoption of the current fishery regulatory measures, would be brief and not more than 3 years (Ita, 1997). The average yield per day for the fishermen will increase and ensure the recovery of *Citharinus citharus*, whose population, by all account, declined in the Late 1970's and early 1980's.

5.3. Changes in Species Composition

Over 100 fish species have been identified in Kainji Lake but less than 20 species of these have sustained the gillnet fishery (Table 3). In the early years after impoundment, the catch composition, by weight and number, in the commercial fishery was dominated by few species such as *Citharinus spp*, *Tilapia*, *Alestes spp* and *Synodontis spp* and, to a lesser extent, by *Labeo spp* and *Bagrus spp*. These high valued species are still prominent in the fishery. There was large variation in catch composition for *Citharinus spp* between 1974 and 1981 but is suddenly gaining prominence again, along with *Synodontis spp* and *Tilapia spp*, as evidenced from the gear based catch assessment survey results.

Table 3. **Species composition (%) by weight in commercial and experimental gillnet data.**

Fish taxon	Old Cas 1970-81	New Cas 1994	New Cas 1995	New Cas 1996	Expt. 69-78	Expt. 1996
Citharinus	20.70	17.01	17.89	14.42	19.04	6.92
Alestes	12.45	2.36	3.19	3.86	13.62	5.05
Labeo	7.34	5.22	9.04	6.21	5.54	11.24
Lates	0.00	8.26	4.27	5.19	6.31	12.35
Synodontis	15.87	17.36	13.51	26.15	12.75	10.89
Tilapia	22.00	8.75	11.38	10.76	6.72	0.88
Chysichthys	1.73	2.09	3.91	8.15	5.86	6.30
Hydrocynus	2.30	5.38	4.05	3.98	13.69	9.20
Auchenoglanis	0.77	6.71	4.79	3.55	0.88	1.48
Gymnarchus	0.97	5.73	5.72	3.34	0.02	0.02
Bagrus	4.98	8.31	9.69	5.30	2.98	10.10
Schilbe	1.14	2.02	1.57	0.50	2.11	0.34
Clarias	1.15	3.20	1.80	11.35	0.19	0.43
Heterobranchus	0.03	2.30	21.20	0.65	0.16	0.03
Others	8.57	5.20	87.98	6.59	10.13	24.77
Total	100	100	100	100	100	100

It is shown in Table 4 that the gillnet fishery causes a huge mortality of the juvenile of *Tilapia* and *Synodontis spp* as the species composition by number was generally high in the years between 1970 and 1981. This was also true for *Citharinus spp,* which contributed about 65% and 71% in number to the 1970 and 1971 fish production respectively.

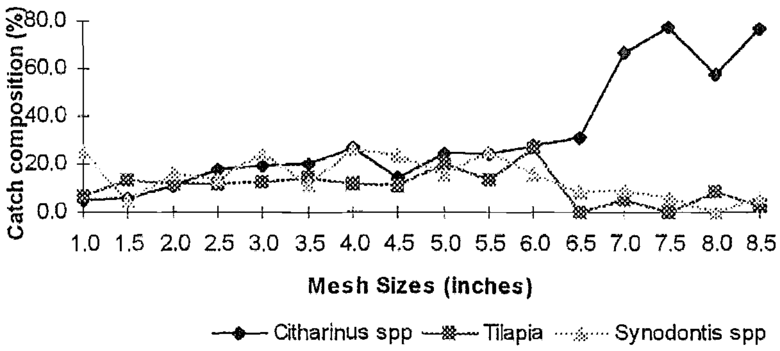
Table 4. **Species composition (%) by number in commercial gillnet fishery, 1970-1986**

Year	1	2	3	4	5	Others
1970	65.24	3.56	11.33	17.81	0.00	2.06
1971	70.76	1.66	9.53	13.67	3.60	0.78
1972	6.50	37.16	3.27	20.80	13.37	18.90
1973	7.80	44.30	3.23	12.65	6.20	25.82
1974	3.76	28.55	1.00	12.41	30.94	23.34
1975	7.74	18.73	19.18	24.45	10.71	19.19
1976	8.69	13.87	5.83	9.97	42.83	18.81
1977	8.69	7.98	6.71	12.46	52.83	11.33
1979	0.00	0.00	0.00	54.14	42.86	5.00
1980	2.31	54.43	2.67	21.36	6.54	12.69
1981	1.02	0.00	4.08	7.65	81.97	5.28
1994	17.64	5.24	5.59	20.94	11.07	39.52
1995	21.09	3.68	17.14	8.37	13.11	36.61
1996	6.80	7.86	8.77	25.87	16.08	34.62

1=*Citharinus*; 2=*Alestes*; 3=*Labeo*; 4=*Synodontis*; 5=Tilapia;

At mesh size level (Figure 4), there is an increasing trend in catch composition with increasing mesh size for *Citharinus spp.* (5% in 1.0" and 76% in the 8.5" mesh sizes) similar to the pattern for Cpue and mean weight. This trend is also exhibited by *Labeo spp,* but to a lesser extent. The catch composition for *Tilapia* also gradually increased with mesh size, to a maximum at mesh 6.0" and declined in catches with mesh sizes of 6.5". There is a rapid decline in catch composition for *Alestes spp* at mesh sizes higher than 4.0".

Figure 6. Variation in catch composition (%) with mesh size of selected species, 1970-96



The above observations are supported by the two sets of gillnet trial data that showed increasing catch composition for *Lates niloticus* with increasing mesh size. The population of *Citharinus spp* was definitely reduced in the later part of the 1970's but has started appearing in catches in significant amount between 1994 and 1996. This species could probably have had highly successful recruitment immediately prior to 1994.

From the above observations it becomes clear that there has been relative stability in the species diversity and composition in the Lake when compared to other great African Lakes like Victoria where the species diversity has been drastically reduced to only three main species reason being the predatory effect by the exotic *Lates niloticus*, introduced in the 1960's, on the local haplochromines and also to a lesser extent.

5.4. Potential Yield from Schaefer Production Model

The old catch assessment survey generated total catch and fishing effort estimates between 1969 to 1978, using the number of fishing boats as the raising factor (Table 5). These data could have been very useful for management of the fishery in the early years, if the data were subjected to further in-depth analysis, and could have provided valuable information on the state of exploitation of the stocks.

The Surplus Production Model was fitted to the data as one species assemblage and this model, applied in this way, has proved very valuable in managing fish stocks in the tropics where only simple statistics of catch and fishing effort are normally available (Seisay, 1991).

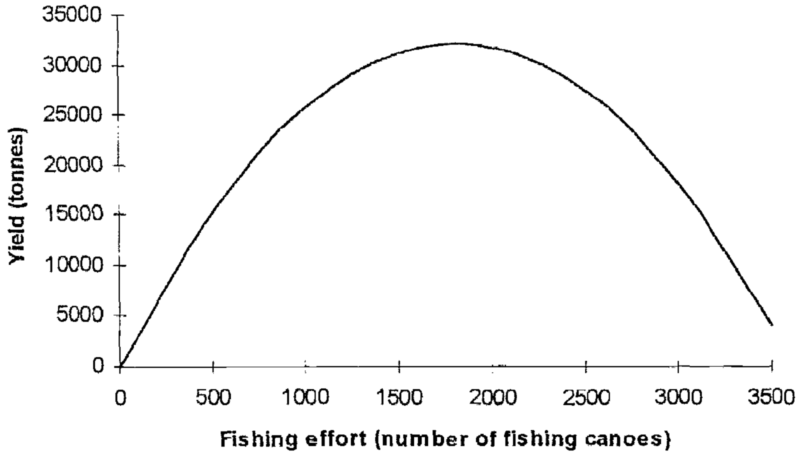
The model gave an estimate of the MSY as 32,166 tonnes and the F_{opt} required to achieve this MSY as 1,814 boats (r = 0.893, d.f = 7). The MSY is calculated here but could also be read off the peak (top) of the parabola in Figure 7 and the resulting effort (F_{opt}) is read off the effort axis.

Table 5. Estimated MSY and F_{opt} for the Kainji Lake fisheries

Year	Catch (Yi) (tonnes)	Fishing effort (fi) Number of canoes*	Cpue (Yi/fi) tonnes/canoe
1969	17,000		
1970	28,600	2600	11.00
1971	11,000	3450	3.19
1972	10,900	3500	3.11
1973	7,300	3450	2.09
1974	6,100	3450	1.77
1975	6,000	3350	1.76
1976	5,800	3300	1.73
1977	4,500	3300	1.36
1978	4,500	3300	1.30

* Original effort data modified in two year moving average;
Estimated MSY = 32,166 tonnes, Estimated F_{opt} = 1,814 canoes

Figure 7. Schaefer yield curve fitted to the Kainji Lake data from table 5



Contrary to earlier observations that the fishery was overfished and has thus stabilized at 5,000 tons as annual yield, the present analysis is suggesting that there was considerable room for expansion and that the fishery was not exploited optimally probably due to use of inefficient fishing gears or fishing by inexperienced fishermen. It is therefore possible that the use of the large number of fishing canoes in the fishery at that time was not necessary since optimal yield was achieved with far lesser number of canoes. It could thus have been appropriate to introduce alternative sources of income to the fishing communities with the overall objective of gradually reducing the fishing effort.

It should be mentioned that the relationship between catch and Cpue only became significant and reasonable when a two-year moving average of effort was considered, which suggests that effort of last year still affects the fisheries the following year by cutting down on the number of recruits entering into the fishery.

The Fox model was also applied but gave poor correlation and unrealistic estimates. The major draw back of this model is that real biological processes which takes place in the fish populations are not described and that processes of growth, recruitment and mortality which alter fish populations are completely ignored.

In the following sections, these parameters are incorporated into yield and biomass prediction of selected species in the cohort and predictive analyses.

5.5. Growth Estimates From Length-at-Age-Data

The rate at which fishes grow per unit time is very relevant in fish stock evaluations since it determines, in conjunction with recruitment into fish stocks, how much biomass is added over a time period, in the case of the present study to carry out detailed stock assessment of individual species with separate catch statistics. Analytical models require data on growth and mortality of individual fish species for evaluation of yield-per-recruitment and biomass.

As mentioned above different methods were used in growth parameter estimation and the estimates were evaluated by growth performance indices (Table 6). The three methods used nearly gave the same results. This is caused by the fact that the data conform exactly to the von Bertalanffy growth function since they were obtained from the equation through back calculation.

Table 6. Estimated growth parameters of selected commercial species in Kainji Lake

Species	L_{inf} (mm)	K (per year)	t_o	r	ϕ (per year)	method
Synodontis	458.39	0.125		0.750	4.419	1
membranaceous	453.00	0.127		0.995	4.416	2
	453.20	0.127		0.778	4.416	3
	458.39	0.128	-0.3065	0.998	4.430	4
Citharinus	668.18	0.317		0.868	5.151	1
citharus	662.59	0.150		0.997	4.819	2
	662.60	0.150		0.902	4.819	3
	668.18	0.323	-0.3875	0.997	5.159	4
Lates niloticus	1559.11	0.240		0.967	5.766	1
	1557.00	0.242		0.998	5.768	2
	1557.00	0.242		0.973	5.768	3
	1559.11	0.239	-0.0955	0.998	5.764	4

1=Gulland and Holt plot; 2=Ford-Walford plot; 3=Chapman method; 4= Von Bertalanffy plot

It is shown that growth estimates differ between species of the same genus and family and therefore separate stock assessment should be carried out for each species. For this reason the three species of *Synodontis* (i.e. *Synodontis membranaceous*, *Synodontis ocellifer* and *Synodontis filamentosus*) should not be combined for stock assessment purposes. The same applies to the three Tilapia species (*Tilapia zillii*, *Oreochromis niloticus* and *Sarotherodon galilaeus*, see Appendix 2).

However, the catfishes, *Bagrus docmac* and *Bagrus bayad*, could be treated as one for stock assessment.

5.6. Estimation of Mortality Rates

Mortality parameters form are an important component of fish population studies. It is important to know the rates at which fish are dying and whether they die more of natural causes or by fishing. For example, natural mortality rate can affect the shape of the yield and biomass curves.

Gulland (1984) stipulates that when the exploitation rate (E) is ≤ 0.5 for a particular species, then the species is considered to be experiencing high fishing intensity. The E values below indicate such high fishing intensity on the species in table 7.

Table 7. Estimated mortality rates for selected commercial species in Kainji Lake

Species	M	Method	Z	(95 % C.L)	r	F	E
Synodontis	0.216	1	1.21	±0.39	0.975	0.994	0.821
membranaceous	0.322	2				0.888	0.734
Citharinus	0.220	1	0.99	±0.55	-0.990	0.770	0.778
citharus	0.535	2				0.455	0.460
Lates	0.231	1	4.66	±0.49	-0.969	4.429	0.950
niloticus	0.535	2				4.125	0.885

1= Pauly; 2= Rikhter and Efanov; M = Natural Mortality rate per year; F=Fishing Mortality per year; Z=Total Mortality per year; E = Exploitation Rate per year

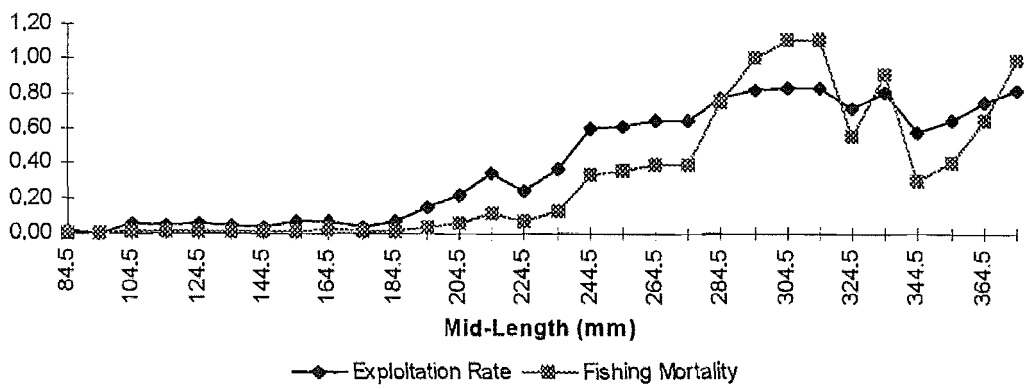
The analysis above suggests that a large part of the total mortality is caused by fishing. Possibly there is no or minimal predatory effect on the three species and the concentration levels of heavy metals such as mercury and lead are not significant enough to be detrimental to these species in any appreciable extent.

5.7. Estimation of Fish Population Number and Recruitment

The population parameters including length/weight relationship were used as input data for cohort analysis. The catch data for each species from the new catch assessment survey were used to obtain the total length composition. The estimated population number and total mortality of the species under review are shown in Appendix 4. The method is a powerful analytical tool since with the population parameters the original population as it was in the lake by calculation back in time from the largest length group can be reconstituted. The estimated number of fish in the smallest length group is taken as the recruitment number that actually enters into the fishery.

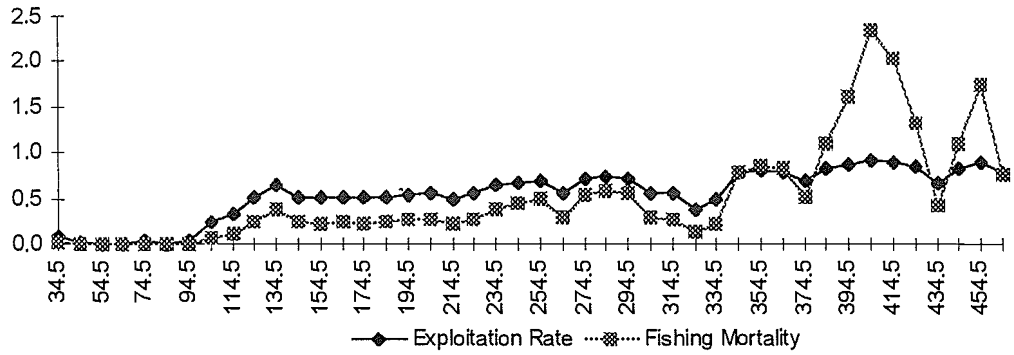
In the case of *Synodontis membranaceous*, fishing mortality starts increasing on length of 245mm, age 5+ years (which is the length and age at maturity of this species, Willoughby, 1974) and peaked at about 300mm (Figure 7). There is a decline in fishing mortality on the larger fish immediately after the peak level. It is likely therefore that large population of old big *Synodontis membranaceous* may be in the Lake. This could again be validated by trawl surveys or the current length frequency sampling programme. It is observed also that fishing mortality is very low and stable on the smaller size groups between 85-230mm.

Figure 8. Fishing intensity on different size groups of *Synodontis membranaceous*



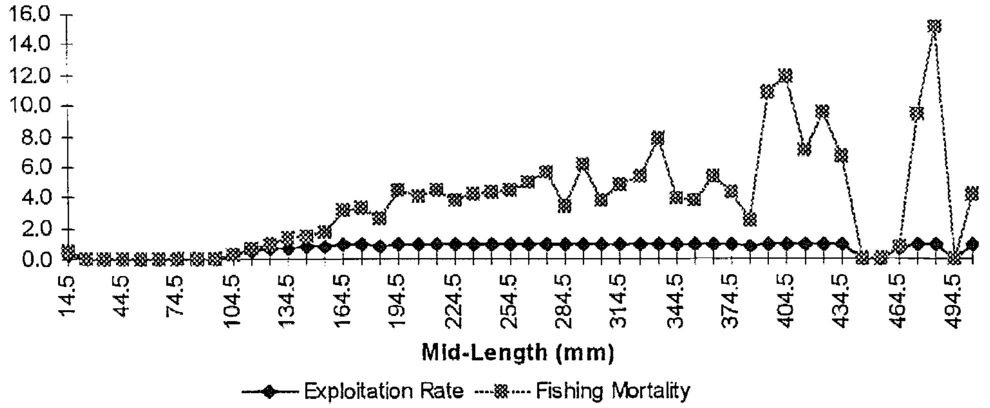
In the case of *Citharinus citharus*, fishing intensity appears to be almost negligible on small fish of sizes between 30-110mm (Figure 8). These could be the juvenile stages still present on the nursery grounds. Recruitment to the fishing grounds starts immediately afterwards when fishing mortality rises slowly and remains steady on length groups from 130-290mm. Fishing intensity rises to a maximum on size groups between 330-430 mm, which includes the length at maturity at 345mm (Arawomo, 1972). This is equivalent to the age at maturity of 3+ years.

Figure 9. Fishing intensity on different size groups of *Citharinus citharus*



Also in the *Lates niloticus*, the juvenile stages of sizes between 20-100mm (Figure 9) appear to be slightly affected by the activities of the commercial fishery. Fishing mortality increases gradually and leveled off on the immature and maturing adults after lengths of 190mm and peaked on stages of lengths between 390-435mm. The species matures at length of 700mm (age 3+) (Balogun 1988). The immature and maturing stages are therefore being largely exploited in the fishery. The older mature stages are therefore not very much available to the commercial fishery, except for long lines. Again trawl investigations will be necessary for confirmation.

Figure 10. Fishing intensity on different size groups of *Lates niloticus*



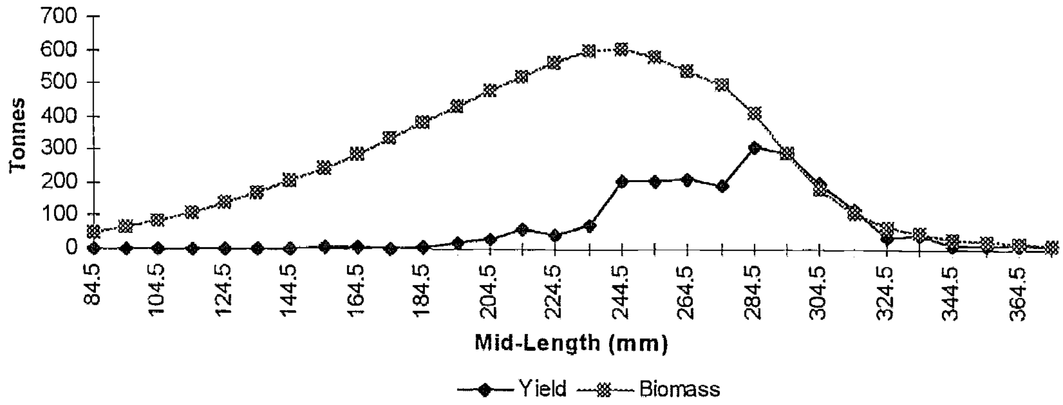
This analysis for *Lates niloticus* is constrained by the lack of length frequency data and so the accurate estimation of population number and mortality is limited. It was therefore not possible to predict long-term yield from the estimated population number. It is hoped that the current ongoing length frequency sampling programme will permit reliable analysis for this species and others.

5.8. Prediction of Yield and Biomass

The yield and biomass per each length were calculated from the estimated population number in cohort analysis above. The estimated number of fish in the smallest length group is taken as recruitment input in the Thompson and Bell analysis.

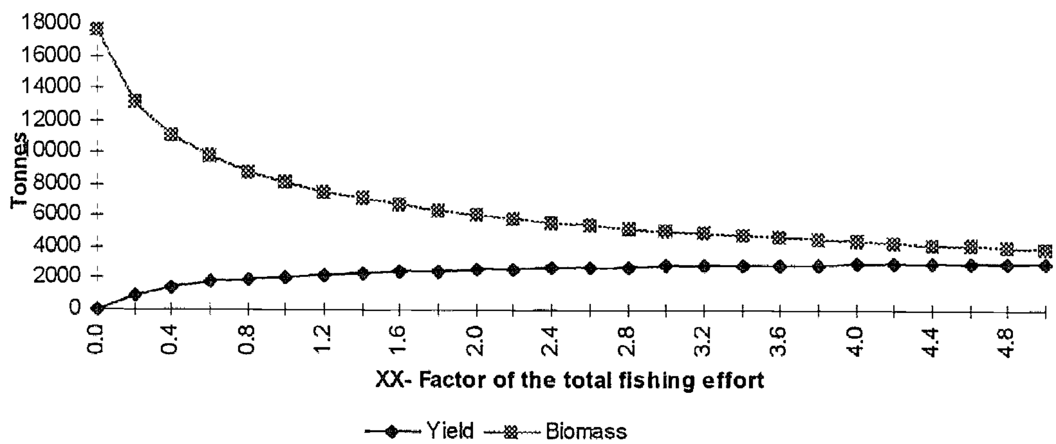
The predicted yield and biomass are shown in Appendix 5. Data in Figure 10 would reveal that a huge quantity of the population of *Synodontis membranaceous* taken in the fishery is between size range of 230-310mm which largely includes the matured stages. The estimated total biomass in the lake is 8,058 tonnes and the bulk of this is between length range of 110-310 mm. Currently only 26% (2,101 tonnes) of this biomass is taken in the commercial fishery. It can be inferred therefore that the current exploitation pattern for this species in the fishery may not be very destructive since it is apparent that the juvenile and immature stages are not fished in any appreciable quantity. In addition, the high fecundity of this species would also ensure the continual replenishment of this stock.

Figure 11. Predicted yield and biomass of *Synodontis membranaceous* by size groups



Varying effort by multiplying the current fishing mortality by various multiplicative factors (XX) gave different yield and biomass levels (Figure 11). The results show that if there is a lakewide ban on fishing for a certain period, the stocks would recover to a biomass level of about 17,610 tonnes in the long-term. Increasing the current fishing effort by 20% (i.e. XX=1.2) would reduce the current biomass from 8,057 tonnes to 7,495 tonnes.

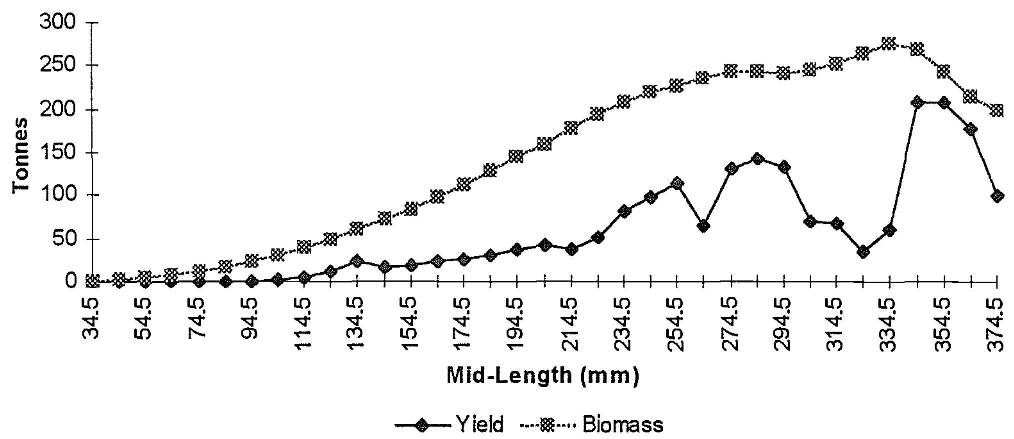
Figure 12. Yield and biomass of *Synodontis membranaceous* at varying effort levels



With increasing fishing effort, the yield will however increase but with a declining biomass. The increase in yield with increased effort is normally the case of fast growing species like *Synodontis membranaceous*. The yield curve will rise to plateau from where it is no longer profitable for the fishermen to continue increasing his effort since the increase in yield will be very marginal at high levels of fishing effort. An inexperienced fisheries manager will advise the administrators to allow more entry into the fishery. In this case, the biomass per recruit curve will be a better guide for the fishery manager. It would appear that, in view of the current status of this stock and the fishing regime upon it, the adherence to the provisions of the current fisheries edicts would ensure the continuity of the stock.

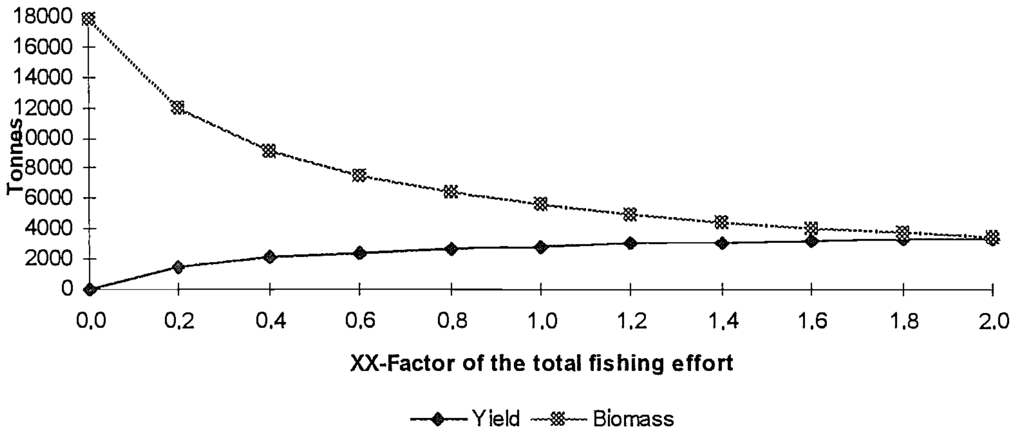
The biomass for *Citharinus citharus* is estimated to be 5,600 tonnes and the estimated catch is 2,888 tons. This suggests that half of the population of this species is currently exploited in the fishery. It is observed from Figure 12 that the greater bulk of the yield of this species are fish with sizes between 210mm to 350mm.

Figure 13. Predicted yield and biomass of *Citharinus citharus* by size groups



It is also predicted that this stock will recover from current biomass of 5,600 tonnes to 18,720 tonnes when fishing is closed for a certain period (Figure 13). On the other hand there is a rapid decline in the biomass predicted in case fishing effort increases significantly. At high effort levels there is a marginal yield with increasing fishing effort. Like in the case of *Synodontis membranaceous*, the yield rises to a plateau with increasing fishing effort. The yield and biomass levels become erratic for very big fish groups suggesting that these stages may be under exploited in the fishery.

Figure 14. Yield and Biomass of *Citharinus citharus* at Varying Effort levels



6. Conclusion and Recommendation

A large part of the analysis above is based on data collected since the formation of the Lake. Apart from the problem of missing data, the quality of some of the old data leaves much to be desired. There was a break down in regular fisheries data collection on the lake after 1981. Data collection resumed in 1993 with the arrival of KLFPP.

The data collected so far is far from adequate for the purpose of stock assessment except for the 1996 experimental gillnet trial data.

However, the current length frequency sampling programme will be very relevant for fish population parameter estimations and comparison to results in this study. For these parameters to be useful they need to be combined with the results of the ongoing catch assessment surveys, as has been done above, for cohort analysis and yield prediction.

In this regards, the project should endeavour to collect catch data on major individual species breakdown instead of species groups. It has already been illustrated in this report that species of the same family can have different population parameters and should therefore not be considered as one species for resource evaluation purposes.

Not-with-standing the above limitation, the analysis detected trends in the fishery with implication for fishery management. In general, abundance indices and mean weight in almost all the major species have declined since the Lake formation. This trend is correlated positively with the declining mesh sizes in the gillnet fishery, with a shift in mode of number of gillnets to illegal mesh size. Immediate compliance with the minimum mesh size regulation and the ban on beach seines is very necessary since the consistent use of small meshed nets could be detrimental to comparatively low fecund species like Tilapia which only produce, on average, between 250-800 eggs per year.

The implementation of the mesh size regulations will result in long term yield for species like *Citharinus spp, Lates niloticus, Labeo spp, Synodontis spp,* Tilapia etc. A major drawback of this regulation is that species like *Alestes, Chysichthys* etc. will remain largely unexploited in the gillnet fishery since they are very important in the small meshed nets.

Interestingly, however, the analysis revealed that there has not been drastic change in catch composition of the gillnet fishery. This suggests that species diversity in the Lake has remained largely stable. This observation was also made by Ita (1993) who concluded that the decline in Cpue has not drastically affected the species composition in the Lake which, under adequate management, could recover its production.

Initially, there was a reduction in the proportion of *Citharinus spp* in the late 1970's with the number of small fish increasing in the catch. But the catch assessment survey, 1994-1996, has indicating a possible recovery of this stock. It is not surprising therefore that the catch rates and mean weights of species like *Citharinus* and *Labeo* is still increasing with increasing mesh size in the fishery.

Annual landings for some of the species under review here have fluctuated widely on annually basis, between 1994-1997, and could be linked to actual variation in yearly biomass due to fast growth, high mortality and variable recruitment. The fishery has been characterized by some few major species like *Citharinus spp.* showing occasional exceptionally strong year classes. This phenomenon has helped so far in sustaining the fishery

The practical implication of increased landings of high value fish like *Citharinus spp, Lates niloticus, Tilapia* and *Labeo spp* in larger mesh sizes is that a fisherman with such a net is more likely to return from a fishing trip with higher cash income than his colleague with under sized gear.

The study has estimated the maximum sustainable yield (MSY) to be 32,166 mt (excluding the clupeids). Since there has not been any serious changes in species composition, the value should be regarded as still appropriate to the current fishery. The current annual yield (excluding the clupeid catch) from the fishery is much lower than the estimated MSY. The estimated optimal effort level required to achieve this MSY is 1,814 boats. An estimated potential yield of 10,000 mt of all species (including clupeids), using morphoedaphic indices and other environmental parameters, was proposed for the Lake (Ita, 1993). This is clearly unrealistic in view of the current fish production levels of the Lake. However, the effort estimate in the present study compares somehow with Ita's (1993) observation which states that, in a regulated fishery, a lake with a maximum surface area of 1,280 Km^2 would be expected to cater for 1,280 fishing canoes. This is low compared with present number of boats. In any case, the current high number of fishing boats could be maintained in the fishery as long as appropriate fisheries measures are in place since it is highly unlikely that the this MSY will be over shot.

The fishing pattern (distribution of fishing mortality over size groups) exhibited by cohort analysis in the three species considered showed that fishing mortality in *Synodontis membranaceous* and *Citharinus citharus* is concentrated on matured stages. Though there are large number of small meshed nets, the fishing mortality on the juvenile/immature stages is not as high as on the matured stages. As long as these matured stages are giving chance to produce at least once before harvested, and considering their high fecundity, the stocks will be replenished continually.

The situation is however different for *Lates niloticus* where the fishery is hitting hard entirely the juvenile/immature populations of this species.

The present fishery should not be allowed to expand beyond any further since the reduction in biomass with increasing effort will far more exceed the corresponding increase in yield, as has been illustrated in this study.

A far more clear picture will emerge at the end of the length frequency data collection by the project when several species will be analyzed in a similar manner. It is proposed that the gillnet trial data be repeated so that the patchy 1996 data becomes more useful to the project. The gillnet experiment is useful for the continuous monitoring of the stocks; this will focus on the density of the species, variation in catch rates and mean weight, mesh selectivity etc.

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Appendix 1: Length-at-age data for major commercial species in Kainji Lake

Species	Length	1	2	3	4	5	6	7	8	9	10
	mm	Age in Years									
1	SL	72	112	155	198	228	254	275			
2	SL	65	95	123	145						
3	SL	60	98	129	153	180					
4	TL	242	354	451	504						
5	TL	349	604	812	976	1091	1198	1296	1331	1370	1420
6	TL	150	277	365	408	443					
7	TL	146	209	235	256						
8	TL	165	295	383	428	456					
9	SL	137	196	237	280	308					
10	SL	145	250	312	356	390					
11	SL	137	249	340	418	485	542	591	634		
12	SL	135	242	322	403	465	356	578	614		

1 = *Synodontis membranaceous*
2 = *Synodontis ocellifer*
3 = *Synodontis filamentosus*
4 = *Citharinus citharus*
5 = *Lates niloticus*
6 = *Sarotherodon galiliaeus*
7 = *Tilapia zillii*
8 = *Oreochromis niloticus*
9 = *Chysichthys nigrodigitatus*
10 = *Auchenoglanis occidentalis*
11 = *Bagrus docmac*
12 = *Bagrus bayad*

Source: Willoughby (1974); Arawomo (1972); Balogun (1988); Akitunde (1976); Ajayi (1976).

Appendix 2: Estimated growth parameters of major commercial species in Kainji Lake

Species	Linf/mm	K	to	r	Phi prime	Method
Synodontis membranaceous	458.39	0.125		0.750	4.419	Gulland/Holt
	453.00	0.127		0.995	4.416	Ford/Walford
	453.20	0.127		0.778	4.416	Chapman
	458.39	0.128	-0.3065	0.998	4.430	von Bertalanffy
Synodontis ocellifer	290.25	0.146		0.899	4.090	Gulland/Holt
	288.90	0.147		0.998	4.089	Ford/Walford
	288.90	0.147		0.912	4.089	Chapman
	290.25	0.147	-0.7180	0.999	4.093	von Bertalanffy
Synodontis filamentosus	336.33	0.142		0.774	4.206	Gulland/Holt
	332.00	0.145		0.994	4.204	Ford/Walford
	332.30	0.145		0.804	4.204	Chapman
	336.33	0.140	-0.4212	0.999	4.200	von Bertalanffy
Citharinus citharus	668.18	0.317		0.868	5.151	Gulland/Holt
	662.59	0.150		0.997	4.819	Ford/Walford
	662.60	0.150		0.902	4.819	Chapman
	668.18	0.323	-0.3875	0.997	5.159	von Bertalanffy

Appendix 2: cont'd

Species	Linf/mm	K	to	r	Phi prime	Method
Lates niloticus	1559.11	0.240		0.967	5.766	Gulland/Holt
	1557.00	0.242		0.998	5.768	Ford/Walford
	1557.00	0.242		0.973	5.768	Chapman
	1559.11	0.239	-0.0955	0.998	5.764	von Bertalanffy
Sarotherodon galiliaeus	497.31	0.446		0.977	5.043	Gulland/Holt
	497.00	0.466		0.995	5.061	Ford/Walford
	496.60	0.466		0.985	5.060	Chapman
	497.31	0.461	0.2133	0.999	5.057	von Bertalanffy
Tilapia zillii	271.80	0.646		0.944	4.679	Gulland/holt
	271.00	0.680		0.970	4.698	Ford/Walford
	271.00	0.680		0.970	4.698	Chapman
	271.80	0.675	-0.1189	0.993	4.698	von Bertalanffy
Oreochromis niloticus	503.11	0.488		0.987	5.092	Gulland/Holt
	502.71	0.500		0.996	5.102	Ford/Walford
	502.71	0.500		0.991	5.102	Chapman
	503.11	0.497	0.1859	0.999	5.100	von Bertalanffy

Appendix 2: cont'd

Species	Linf/mm	K	to	r	Phi prime	Method

Appendix 3: Estimated parameters of length/weight relationship

Species	Log a	Log b
Synodontis membranaceous	-4.46	2.980
Citharinus citharus	-5.57	3.052
Lates niloticus	-4.36	2.880

Appendix 4: Results from Cohort analysis for selected species

A. *Synodontis membranaceous*

length L1/mm	class L2/mm	Actual number caught	Estimated population number of survivors	Estimated total mortality Z
80	89	7,161	12,042,302	0.2229
90	99	0	11,492,560	0.2200
100	109	28,643	10,960,700	0.2321
110	119	21,482	10,411,476	0.2293
120	129	28,643	9,881,340	0.2327
130	139	21,482	9,356.054	0.2298
140	149	14,321	8,850,053	0.2267
150	159	35,804	8,363,056	0.2371
160	169	35,804	7,866,896	0.2376
170	179	14,321	7,383,799	0.2272
180	189	28,643	6,934,754	0.2349
190	199	71,607	6,483,834	0.2586
200	209	107,411	6,004,318	0.2805
210	219	193,339	5,506,122	0.3352
220	229	114,571	4,943,462	0.2926
230	239	186,178	4,481,570	0.3459
240	249	443,964	3,970,054	0.5567
250	259	393,839	3,235,994	0.5719
260	269	365,196	2,595,970	0.6119
270	279	300.749	2,025,777	0.6151
280	289	429,642	1,557,545	0.9730
290	299	365,196	1,002,377	1.2209
300	309	229,142	556,913	1.3254
310	319	121,732	282,165	1.3270
320	329	35,804	136.240	0.7770
330	339	35,804	86,296	1.1354

A. *Synodontis membranaceous* cont'd

length L1/mm	class L2/mm	Actual number caught	Estimated population number of survivors	Estimated total mortality Z
340	349	7,161	41,888	0.5144
350	359	7,161	29,376	0.6241
360	369	7,160	18,317	0.8658
370	379	7,161	8,764	1.2291
TOTAL		3,659,121	146,509,972	0.5464

Appendix 4: cont'd

B. *Citharinus citharus*

length L1/mm	class L2/mm	Actual number caught	Estimated population number of survivors	Estimated total mortality Z
30	39	15,999	8,008.017	0.2581
40	49	4,000	7,806,391	0.2248
50	59	0	7,619,376	0.2200
60	69	0	7,437,796	0.2200
70	79	8,000	7,257,616	0.2299
80	89	0	7,070,140	0.2200
90	99	8,000	6,893,802	0.2300
100	109	55,998	6,710,197	0.2911
110	119	87,997	6,480,879	0.3339
120	129	179,994	6,222,925	0.4602
130	139	275,992	5,878,053	0.6063
140	149	163,995	5,444,097	0.4611
150	159	151,995	5,131,240	0.4525
160	169	147,995	4,835,432	0.4557
170	179	139,995	4,549,303	0.4523
180	189	135,995	4,276,737	0.4553
190	199	143,995	4,013,615	0.4806
200	209	139,995	3,748,063	0.4858
210	219	107,996	3,492,204	0.4346
220	229	127,996	3,273,515	0.4866
230	239	175,994	3,039,880	0.6097
240	249	187,993	2,764,524	0.6696
250	259	191,993	2,484,543	0.7214
260	269	99,997	2,208,312	0.5019
270	279	175,994	2,030,277	0.7582
280	289	171,994	1,782,337	0.8071

B. *Citharinus citharus* cont'd

length L1/mm	class L2/mm	Actual number caught	Estimated population number of survivors	Estimated total mortality Z
290	299	143,995	1,545,894	0.7710
300	309	67,998	1,344,405	0.5046
310	319	59,998	1,223,847	0.4881
320	329	27,999	1,114,616	0.3519
330	339	43,999	1,039,899	0.4376
340	349	139,995	951,417	0.9980
350	359	127,996	771,834	1.0793
360	369	99,997	611,068	1.0400
370	379	51,998	484,243	0.7239
380	389	91,997	409,544	1.3120
390	399	95,997	299,013	1.8262
400	409	83,997	189,867	2.5611
410	419	39,999	97,976	2.2426
420	429	15,999	53,627	1.5298
430	439	4,000	34,940	0.6500
440	449	8,000	28,893	1.3207
450	459	8,000	19,295	1.9634
460	469	8,000	10,285	0.9900
TOTAL		4,019,866	140,689,934	0.7345

Appendix 4: cont'd

C. *Lates niloticus*

length L1/mm	class L2/mm	Actual number caught	Estimated population number of survivors	Estimated total mortality Z
10	19	35,984	5,419,893	1.0300
20	29	0	5,306,132	0.5350
30	39	0	5,229,294	0.5350
40	49	3,998	5,153,076	0.5633
50	59	0	5,073,502	0.5350
60	69	0	4,998,579	0.5350
70	79	0	4,924,272	0.5350
80	89	0	4,850,581	0.5350
90	99	3,998	4,777,504	0.5645
100	109	27,987	4,701,066	0.7441
110	119	91,958	4,601,458	1.2360
120	129	115,947	4,439,313	1.4471
130	139	151,931	4,255,356	1.7781
140	149	159,927	4,038,038	1.9066
150	159	183,916	3,815,730	2.1985
160	169	315,856	3,572,666	3.6173
170	179	295,865	3,201,986	3.7393
180	189	215,901	2,856,722	3.1183
190	199	327,850	2,596,108	4.9178
200	209	259,881	2,228,238	4.5363
210	219	247,887	1,933,609	4.9242
220	229	187,914	1,655,507	4.3674
230	239	175,920	1,441,360	4.6414
240	249	159,927	1,242,521	4.8465
250	259	139,936	1,062,749	4.9189
260	269	135,938	905,736	5.5370

C. *Lates niloticus* cont'd

length L1/mm	class L2/mm	Actual number caught	Estimated population number of survivors	Estimated total mortality Z
270	279	127,942	755,258	6.1897
280	289	63,971	615,212	3.8766
290	299	99,954	540,999	6.6540
300	309	51,976	432,306	4.3674
310	319	55,974	373,074	5.3469
320	329	51,976	310,876	5.8975
330	339	59,973	253,714	8.3240
340	349	23,989	189,622	4.4531
350	359	19,991	162,357	4.3118
360	369	23,989	139,535	5.8883
370	379	15,993	113,148	4.8366
380	389	7,996	95,166	3.0048
390	399	27,987	85,438	11.3440
400	409	19,991	56,066	12.4060
410	419	7,996	35,174	7.5180
420	429	7,996	26,565	10.0760
430	439	3,998	18,120	7.1745
440	449	0	13,800	0.5350
450	459	0	13,525	0.5350
460	469	0	13,254	1.3787
470	479	3,998	12,986	9.9177
480	489	3,998	8,760	15.6810
490	499	0	4,620	0.5350
500	509	3,998	4,524	4.6600
Total		3,922,207	98,555,089	4.1751

Appendix 5: Predicted yield and biomass for selected species

A. *Synodontis membranaceous*

i) Predicted yield and biomass per length group

Length class L1 mm	L2 mm	Yield in tonnes	Biomass in tonnes
80	89	0.14	47.66
90	99	0.	65.20
100	109	1.04	86.12
110	119	1.03	110.49
120	129	1.76	138.45
130	139	1.66	170.04
140	149	1.37	205.41
150	159	4.18	244.20
160	169	5.04	286.03
170	179	2.40	331.44
180	189	5.67	380.11
190	199	16.60	429.72
200	209	28.91	478.02
210	219	59.99	520.84
220	229	40.72	561.05
230	239	75.34	598.42
240	249	203.46	604.31
250	259	203.39	577.91
260	269	211.55	539.79
270	279	194.59	492.57
280	289	309.27	410.72
290	299	291.39	291.11
300	309	201.96	182.71
310	319	118.14	106.72
320	329	38.14	68.48

A. *Synodontis membranaceous* cont'd

i) Predicted yield and biomass per length group

Length class L1 mm	L2 mm	Yield in tonnes	Biomass in tonnes
330	339	41.75	45.61
340	349	9.12	30.97
350	359	9.93	24.57
360	369	10.79	16.70
370	379	11.64	11.77
TOTAL		2,100.99	8,058.37

A. *Synodontis membrannaceous* cont'd

ii) Yield and biomass at varying levels of effort for *Synodontis membranaceous*

XX-Factor	Yield/ tonnes	Biomass/ tonnes	
0.0	0.00	17,609.90	
0.2	974.77	13,176.20	
0.4	1,444.18	11,042.50	
0.6	1,737.91	9,707.33	
0.8	1,944.80	8,766.93	
1.0	2,100.99	8,058.37	Current fishery
1.2	2,224.52	7,495.45	
1.4	2,325.48	7,036.53	
1.6	2,410.09	6,651.96	
1.8	2,480.38	6,323.35	
2.0	2,545.13	6,038.15	

Current effort= 11.155 standardized gillnets i.e. efforts of others gears standardized into gilinet effort

XX= a multiplicative factor of fishing effort, that is XX=0.2 implies decreasing the current effort of 11,155 standard gillnet units by 20 %

Appendix 5: cont'd

B. *Citharinus citharus*

i) Predicted yield and biomass per length group

Length L1 mm	class L2 mm	Yield in tonnes	Biomass in tonnes
30	39	0.04	1.04
40	49	0.01	2.41
50	59	0	4.44
60	69	0	7.36
70	79	0.11	11.34
80	89	0.	16.51
90	99	0.23	23.02
100	109	2.20	30.89
110	119	4.56	40.03
120	129	12.04	50.14
130	139	23.37	60.50
140	149	17.29	71.71
150	159	19.65	84.52
160	169	23.17	98.31
170	179	26.25	112.97
180	189	30.22	128.42
190	199	37.59	144.26
200	209	42.59	160.23
210	219	38.01	177.10
220	229	51.77	194.23
230	239	81.31	208.67
240	249	98.67	219.44
250	259	113.88	227.11
260	269	66.72	236.66
270	279	131.50	244.35

B. *Citharinus citharus* cont'd

i) Predicted yield and biomass per length group

Length class L1 mm	L2 mm	Yield in tonnes	Biomass in tonnes
280	289	143.34	244.14
290	299	133.35	242.01
300	309	69.73	244.98
310	319	69.90	253.26
320	329	34.86	264.41
330	339	60.10	276.20
340	349	209.22	268.92
350	359	208.75	242.93
360	369	177.53	216.50
370	379	100.27	198.97
380	389	192.25	176.05
390	399	216.96	135.08
400	409	204.92	87.53
410	419	105.13	51.98
420	429	45.23	34.53
430	439	12.14	28.23
440	449	26.02	23.64
450	459	27.85	15.98
460	469	29.77	38.66
TOTAL		2,888.52	5,599.63

B. *Citharinus citharus* cont'd

ii) Yield and biomass at varying effort levels for *Citharinus citharus*

XX-Factor	Yield tonnes	Biomass tonnes	
0.0	0.00	18,720.20	
0.2	1,479.00	11,997.40	
0.4	2,095.75	9,194.01	
0.6	2,460.68	7,535.27	
0.8	2,707.14	6,414.99	
1.0	2,888.52	5,599.63	Current fishery
1.2	3,023.60	4,976.56	
1.4	3,132.13	4,483.23	
1.6	3,220.36	4,082.17	
1.8	3,293.60	3,749.25	
2.0	3,355.44	3,469.19	

Current effort= 11.155 standardized gillnets i.e. efforts of others gears standardized into gillnet effort

XX= a multiplicative factor of fishing effort, that is XX=0.2 implies decreasing the current effort of 11,555 standard gillnet units by 20 %